Submitted to: 2001 Particle Accelerator Conference
June 18 - 22, 2001
Chicago, IL

BNL - 67988

SCHOTTKY MEASUREMENTS DURING RHIC 2000 *

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Abstract

The 2GHz Schottky system was a powerful diagnostic during RHIC 2000 commissioning. A continuous monitor without beam excitation, it provided betatron tune, chromaticity, momentum spread, relative emittance, and synchrotron tune. It was particularly useful during transition studies. In addition, a BPM was resonated at 230MHz for Schottky measurements.

1 INTRODUCTION

With the 17dB advantage in signal-to-noise ratio enjoyed with Au beams relative to protons, the Schottky spectrum was expected to be an extremely valuable source of information at RHIC. While this expectation proved to be accurate, it was also true that the Schottky system was quite useful during operations with polarized protons.

Two high-frequency cavities from Lawrence Berkeley National Laboratory[1] are used to detect Schottky signals from both beams. The transverse modes are TM120 and TM210 at 2.069±0.002GHz. They have measured Q of 4700, and are separated by 4 MHz. A longitudinal mode is at 2.741GHz. The signals are down-converted to 2MHz and amplified in the tunnel, then transported to an external 10MHz bandwidth FFT analyzer. Data is provided to the control system through LabVIEW communicating with the FFT analyzer via TCP, as well as through a remote Xterm scope application.

2 MEASUREMENTS DURING RAMPING

The usefulness of the 2GHz Schottky system during acceleration of Gold beams is limited by the large width and resulting overlap of the revolution and betatron lines at and near injection energies, where the relativistic slip factor is large. In addition, the 0.4% increase in RHIC revolution frequency during ramps results in line movement of 8MHz at 2GHZ during the ramp, causing rapid sweeping of the spectral lines across the 400KHz wide cavity resonance. The possibility of using a beam-synchronous frequency for down conversion was investigated and discarded because of bandwidth problems in the available frequency multiplier, and more significantly because of the timing system interface required to implement the line-hopping needed to track the cavity resonance as it would then sweep under the stationary spectrum. A consequence was that averaging could not be used to decrease noise during ramps. Solutions to the problems arising out of the non-stationary spectrum were also hampered by limitations in the interface in the FFT analyzer, which permitted transfer of spectra at a maximum rate of about 1Hz. All of these problems have been effectively dealt with in a 238MHz Schottky/PLL/Tune Feedback system, which is described briefly at the end of this paper and in more detail elsewhere in these proceedings[2,3].

2.1 Spectrum up the ramp

A LabVIEW application that centered the revolution line in each raw spectrum and permitted visual averaging of the resulting spectrogram was created to partially circumvent these difficulties during RHIC 2000. Figure 1 is a spectrogram acquired during a complete ramp from γ=10.3 to γ=70. The span of the spectrum is 78KHz, the RHIC revolution frequency, so that only a single revolution line and set of betatron sidebands are seen. The white horizontal lines are markers generated to indicate a fractional tune of 0.25.

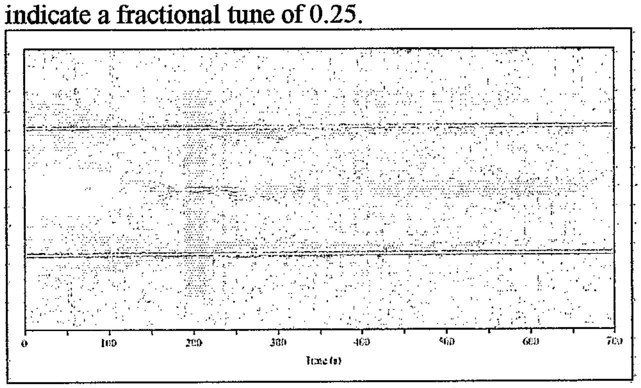

Figure 1: Spectrogram of a complete ramp

The beginning of the ramp is at the left of the figure. Betatron sidebands are not resolved until well into the ramp. All lines narrow as transition is approached. Broadband noise is observed immediately following transition; its source is discussed in greater detail in the following section. Sidebands remain clearly resolved until the end of the ramp, allowing easy measurement of tune. Note the asymmetry between sidebands in the latter part of the ramp, indicating non-zero chromaticity.

2.2 Time Capture at First Transition Crossing

For the purpose of obtaining detailed spectra over a short time span, the analyzer could be used in a mode in which 5 seconds of raw data was captured, and then transformed to the frequency domain during post-processing. This mode was triggered shortly before transition to permit detailed study of transition crossing. Figure 2 is a spectrogram of signals from the horizontal resonance of the blue ring cavity, acquired during the first successful transition crossing in RHIC. The spectrum width is again 78KHz. The revolution line and betatron sidebands are sweeping from lower left to upper

*Work performed under the auspicies of the US DOE

right. The intense red line sweeping from lower right to upper left is an artifact, thought to result from mixer

Two sets of betatron sidebands of unequal intensity appear, caused by weak coupling of the accelerator. Transition is crossed at approximately 0.3 seconds, where the sidebands cross due to nonzero chromaticity.

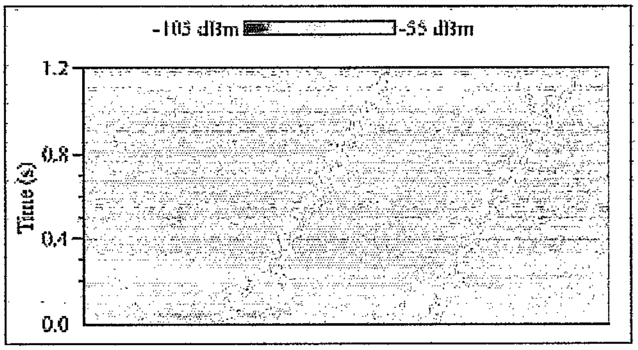

Figure 2: Spectrogram of transition crossing

Figure 3 is a waterfall display of the RF wall current monitor. It shows longitudinal bunch shape, and was acquired concurrently with Figure 2. Transition occurs approximately 0.05 seconds into the plot, at the point where bunch traces shift from the left edge to the right. The plot shows an oscillation in bunch length with a period of 0.08 seconds, twice the synchrotron frequency, indicating a quadrupole oscillation in longitudinal phase space.

The broadband noise in the Schottky spectrum occuring after transition also has a period of 0.08 seconds, leading us to believe that the quadrupole oscillations were just sufficient to drive the tails of the transverse distribution into the beampipe walls in high dispersion regions (including the location of the Schottky cavities) at times of maximum intrabunch momentum spread, causing currents which excited broadband noise in the cavity. The phenomenon of broadband noise in the Schottky spectrum during beam loss is frequently observed at RHIC, for instance at transition in Figure 1 above.

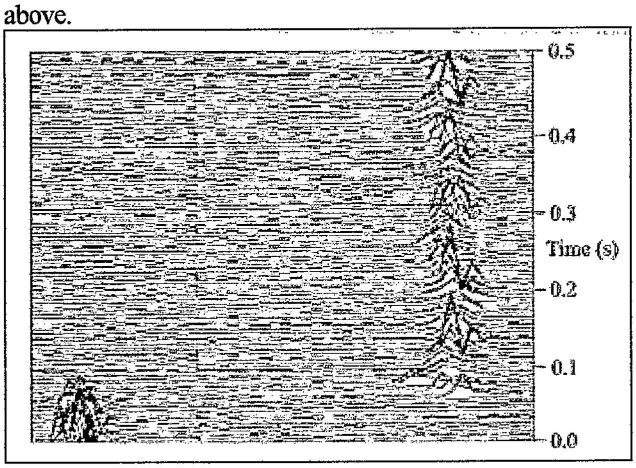

Figure 3: Bunch shape at transition.

bleedthrough of the revolution line from the vertical spectrum.

2.3 *Measurement of α_1*

The chromatic nonlinearity parameter α_1 can be measured by comparing synchrotron frequency with beam radius. Measurement of synchrotron frequency from spectra of signals from the longitudinal resonance of the yellow ring cavity were used to estimate a value of α_1 in the RHIC yellow ring of -1.15 ± 0.10 [4].

3 MEASUREMENTS AT STORE

Despite the poor S/N ratio relative to Gold, the Schottky system provided useful data during operation with protons. Figure 4 shows the front panel of a LabVIEW application that read averaged spectra from the FFT analyzer every 10 seconds, then analyzed the spectra to compute betatron tunes, chromaticity, momentum spread, and transverse emittance. The data shown spans about 100 minutes, during which time polarization was measured[5] for 3 separate fills. During this time horizontal tune and chromaticity can be seen to decrease gradually, and vertical tune and chromaticity gradually increase. Emittance growth during the store is a result of interaction of the beam with the polarimeter target.

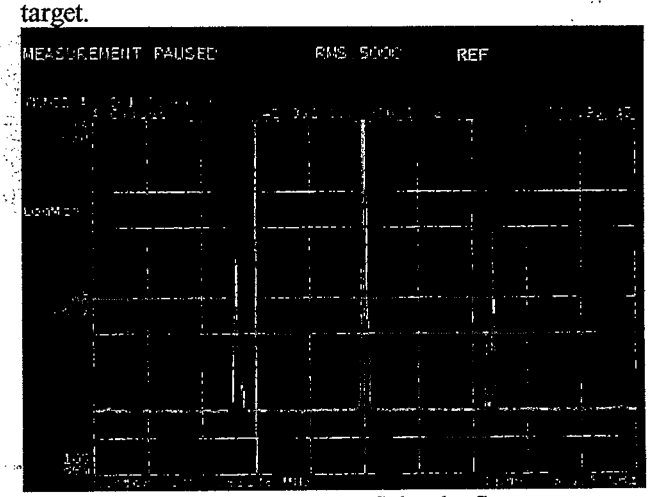

Figure 5: Low Frequency Schottky Spectrum

4 LOW FREQUENCY SCHOTTKY

For a variety of reasons, including the limitations discussed earlier in this paper, it was decided to resonate a BPM[3] at about 230MHz. Figure 5 shows a horizontal spectrum obtained from that BPM. Weak vertical lines are visible. Coherence at the upper sidebands is from beam excitation during PLL measurements.

5 ACKNOWLEDGEMENTS

The authors are grateful to Mike Harrison and Tom Shea for initiating and maintaining the collaboration with LBNL that resulted in construction of this system, and to David Goldberg for many helpful conversations.

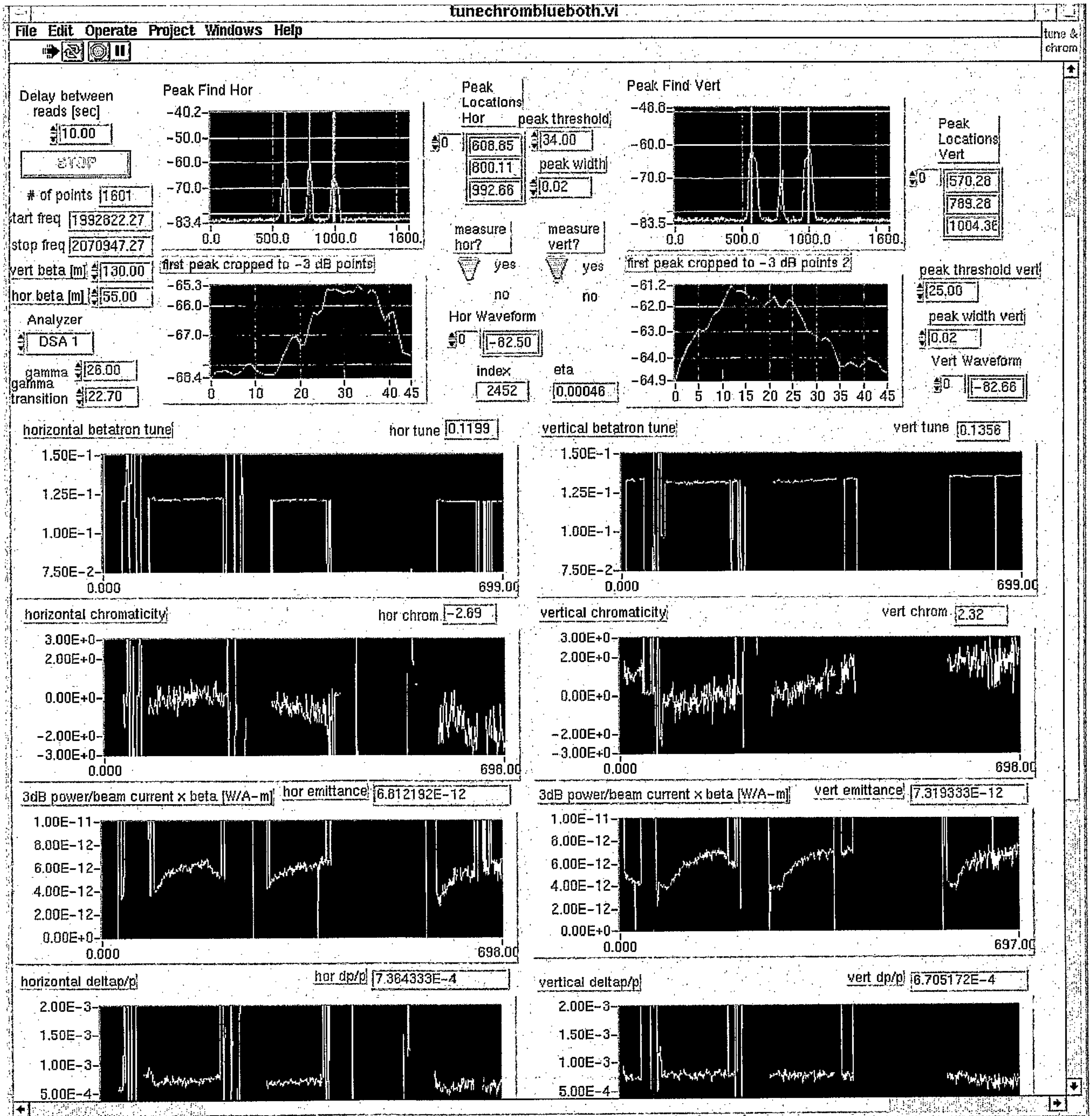

Figure 4: Beam Parameters Derived from Proton Schottky Spectra at Store

6 REFERENCES

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Work performed under the auspices of the US Department of Energy.